Chapter 42

PERSONAL LEARNING ASSOCIATES AND THE NEW LEARNING ENVIRONMENT

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Much education, training, problem solving, performance aiding, decision aiding, and the like, may, in the not-distant future, rely on dialogues or conversations with personalized computer based devices, which might be called personal learning associates (PLAs). It further seems likely that these devices will be used as portals into virtual worlds and virtual environments where these dialogues will continue in combination with other experiences, contexts, and conditions.

Functionally, such a PLA-inhabited world might rely on three key components:

1. A global information infrastructure, such as today's World Wide Web, populated by sharable digital objects. These objects could be content for display, such as text, video, virtual "islands," and avatars. They could also be nondisplay materials, such as algorithms, instructional strategies, software tools, and databases.
2. Servers to locate and retrieve these digital objects and assemble them to support interactions with users and learners.
3. Devices that serve as PLAs for users and learners. They could be handhelds and laptops so that they are available on demand, anytime, anywhere. They could also be hosted on platforms ranging from integrated circuits to mainframes. The PLAs could be linked for use by groups of geographically dispersed learners working collaboratively. They will be personal accessories, but they need not be limited to individual uses.

TRENDS

There are historical and technological trends in education, training, and elsewhere that point to the likelihood, if not inevitability, of PLA devices and capabilities. In discussing these trends we need a generic term for education, training, performance aiding, problem solving, decision aiding, and similar capabilities. For convenience they are lumped together here and called "learning."

SOME HISTORICAL TRENDS IN LEARNING

In the primordial beginnings and for perhaps 100,000 years thereafter, learning involved direct, in-person interactions between learners and a sage. Seven thousand or so years ago we learned how to write, which effected a major revolution in learning. People with enough time and resources could study the words of sages without having to rely on face-to-face interaction or the vagaries of human memory. Learning began to move in an on-demand, anytime, anywhere direction.

The next step was the development of books (that is, something beyond mud or stone tablets). As discussed by Kilgour (1998), books were based on papyrus and parchment rolls until about 300 B.C. when the Romans began to sew sheets of parchment together into codices. These were cheaper to produce because they were based on locally available parchment made from animal skin and allowed content to be placed on both sides of the sheets.

Use of paper prepared from linen and cotton in about A.D. 100 (China) and A.D. 1200 (Europe) made books even less expensive. Their lowered costs made them more available to a literate and growing middle-class who, in turn, increased the demand for more cost reductions, more books, and more of the learning they provided. This demand led to the introduction of books printed from moveable type, first in China around A.D. 1000, and later in Europe in the mid-1400s (Kilgour, 1998). Learning then continued to become more widely and inexpensively available on demand, anytime, anywhere.

Next, after about 500 years, comes the computer. With its ability to adapt the sequence and type of operations based on conditions of the moment—or microsecond—computer technology may effect yet another revolution in learning. While preserving the capabilities of writing and books to present learning content on demand, it can also provide guidance and tutorial interactions as needed by individual learners. This combination of learning and individually tailored interactivity is not something books, movies, television, or videotape technologies can do to any appreciable degree. It is a new and significant capability for learning.

In short, the progression of learning across human history appears to be toward increased on-demand, anytime, anywhere access to learning. Aided by computer technology, it seems likely to continue. At least that is the argument presented here.

TECHNOLOGY

Many technologies evolve in directions that no one foresees. We had steam engines before railways, wireless telegraph before radio, microwave transmitters before microwave ovens, the Internet before the Web, and so forth. Still, there may be value in trying to envision where our technologies may be taking us. Knowing in advance where we are going can help us get there—or avoid doing so, should that seem more prudent.

It has been suggested that the future is already here, but unrecognized and unevenly distributed. When it comes to learning and learning environments we might ask what is currently unrecognized and unevenly distributed to see where these environments, and we, may be headed. We might begin by hazarding a list of possibly relevant trends and capabilities that are already at hand. Such a list could include the following:

Moore's Law. In 1965 Gordon Moore, a co-founder of Intel Corporation, noted casually that engineers were doubling the number of electronic devices on chips every year. If we expand Moore's time estimate to 18 months, our expectations fit reality quite closely (Brenner, 1997). This pace of development seems likely to continue. Gorbis and Pescovitz (2006) found that about 70 percent of IEEE (Institute of Electrical and Electronic Engineers) Fellows expect Moore's Law to continue holding for at least 10 more years. About 35 percent of them expect it to continue beyond that, up to 20 years. The major consequence of Moore's Law for PLAs is that the technology needed to support them will become increasingly more compact and affordable.

Computer Communications and Networking. The most dramatic and globally pervasive manifestations of computing in our daily lives seem to be the Internet and the World Wide Web. Web use grew about 266 percent between 2000 and 2007, with more than 1.3 billion learners and users of all sorts worldwide as of December 2007 (Internet World Stats, 2007). The Web and the evolving global information infrastructure have made vast amounts of human information—and misinformation—globally accessible. Tens of thousands of people can participate in massively multiplayer online games, such as *EverQuest, Final Fantasy, RuneScape,* and *World of Warcraft.* Similar multitudes of globally dispersed learners may soon be participating in virtual environments through PLAs.

The Semantic Web. The Semantic Web (Berners-Lee, Hendler, & Lassila, 2001), which is being developed under the auspices of the World Wide Web Consortium, should improve cooperation between computers and human beings by imbuing Web information with meaning and ontological connections. These connections are expected to expose semantic linkages between disparate bodies of knowledge regardless of how different they may appear to be at first (for example, Chandrasekaran, Josephson, & Benjamins, 1999). They will make it possible to develop increasingly powerful, accurate, and comprehensive models of learners for use in tailoring learning environments and their interactions to individual needs and interests (Dodds & Fletcher, 2004). They may add substantially to the adaptability and realism of virtual environments.

Computer Graphics, Video, and Animation. The validity of the multimedia principle, which states that people can absorb more information from words and pictures presented together than from words alone, seems well established by research and ensuing cognitive theory (Fletcher & Tobias, 2005). Enhancements in multimedia capabilities (for example, graphics, video, and animation) now available in virtual environments, and therefore available to PLAs, increase the power, flexibility, and functional range of learning environments and, thanks to the multimedia principle, the retention and transfer of what is learned from them.

Learning Objects. Object-oriented applications are becoming ubiquitous. The development of specifications to make learning objects accessible, interoperable, reusable, and durable is an integral part of this trend. These specifications have been described elsewhere (for example, Fletcher, Tobias, & Wisher, 2007; Wiley, 2000). The objects are packaged in metadata, which describes what is in the package, and are being made available on the global information infrastructure, allowing object-oriented applications, such as we might find in PLAs, to identify, locate, and access them, thereby enhancing the flexibility, responsiveness, and adaptability of leaning environments.

Natural Language Processing. The steadily growing capabilities of computer technology to participate in natural language conversations (for example, Graesser, Gernsbacher, & Goldman, 2003) will significantly enhance the mixed initiative dialogues in which participants, both computer generated and real, participating in learning environments can initiate interactions. One can imagine turning an avatar loose on the global information infrastructure to find advice or to answer a question by locating relevant learning objects and/or engaging humans and other avatars in conversations and returning to report when it judges itself ready. Language barriers should diminish in virtual environments as avatars and human participants become increasingly able to interact using a variety of languages (for example, Chatham, in press). Given the economic windfall promised by reliable natural language understanding by computers, it seems likely that these capabilities will continue to develop.

Individualized, Computer-Assisted Learning. Major improvements over classroom instruction occur when education and training can be presented in tutorial, individualized interactions. The difference can amount to two standard deviations as, for instance, Bloom (1984) found. However, we cannot afford a single human instructor for every learner nor a single advisor for every problem solver. A solution to this problem may be found, as Fletcher (1992) and Corbett (2001) have suggested, by using computers to make affordable the substantial benefits of individualized, tutorial learning suggested by Bloom's research.

Computer technology captured these benefits early on. Since the 1960s they have tailored (a) rate of progress for individual learners, (b) sequences of instructional content and interactions to match each learner's needs, (c) content itself—providing different learners with different content depending on what they have mastered, and (d) difficultly levels to ensure that the tasks for the learner are not so easy as to be boring or so difficult as to seem impossible. These capabilities have been available and used in computer based instruction from its inception (for example, Coulson, 1962; Galanter, 1959; Suppes, Jerman, & Brian, 1968).

By the early 1970s, the effectiveness of using computer technology to individualize learning was generally recognized (for example, Ford, Slough, & Hurlock, 1972; Vinsonhaler & Bass, 1972). Findings from many studies comparing the use of computers in learning to standard classroom practice may be summarized, statistically, by a "rule of thirds." This rule suggests that the learning capabilities we would expect to find on computer based devices, such as PLAs, can reduce the cost of delivering instruction by about one-third and, beyond that, either reduce instructional time to reach instructional goals by about one-third (holding learning constant) or increase the skills and knowledge acquired by about one-third while holding instructional time constant.

As a statistical summary that is silent about cause, the rule of thirds is compatible with Clark's (1983) often-cited point that it is not technology itself, but what we do with it that matters. Still, the demonstrably attainable savings that the rule of thirds reports in time to learn can be expected to be found in the use of PLAs and could reduce the costs of specialized skill training in the Department of Defense by as much as 25 percent (Fletcher, 2006). Similar cost savings are attainable through the use of PLAs as performance aids in equipment maintenance (Fletcher & Johnston, 2002).

Intelligent Tutoring Systems. The key and historical difference between computer-assisted instruction and intelligent tutoring systems is a substantive matter and more than a marketing term. When intelligent tutoring was first introduced into computer-assisted instruction, it concerned quite specific goals that were first targeted in the 1960s (Carbonell, 1970; Fletcher & Rockway, 1986; Sleeman & Brown, 1982).

Two defining capabilities were that intelligent tutoring systems should

- Allow either the system or the learner to ask open-ended questions and initiate a "mixed-initiative" dialogue as needed or desired for learning. Mixed-initiative dialogue requires a language that is shared by both the system and the learner. Natural language has been a frequent and continuing choice for this capability (for example, Brown, Burton, & DeKleer, 1982; Collins, Warnock, & Passfiume, 1974; Graesser, Person, & Magliano, 1995; Graesser, Gernsbacher, & Goldman, 2003), but the language of mathematics, mathematical logic, electronics, and other well-structured communication systems have also been used (Barr, Beard, & Atkinson, 1975; Suppes, 1981; Sleeman & Brown, 1982; Psotka, Massey, & Mutter, 1988).
- Generate learning material and interactions on demand rather than require developers to foresee and prestore all such materials and interactions needed to meet all possible eventualities. This capability involves not just generating problems tailored to each learner's needs, but also providing coaching, hints, critiques of completed solutions, appropriate and effective teaching strategies, and, overall, the interactions and presentations characteristic of individualized, tutorial learning environments. Generative capability remains key to the full range of PLA capabilities envisioned here.

Early applications such as BIP in computer programming (Barr, Beard, & Atkinson, 1975), BUGGY in subtraction (Brown & Burton, 1978), EXCHECK in mathematical logic (Suppes, 1981), SOPHIE in electronic troubleshooting (Brown, Burton, & DeKleer, 1982), and others demonstrated that the necessary capabilities to model subject matter and match it with models of the learner and generate interactions on demand and in real time are within our technical grasp. Development of these capabilities has continued to improve their performance (for example, Luckin, Koedinger, & Greer, 2007; McCalla, Looi, Bredeweg, & Breuker, 2005; Polson & Richardson, 1988; Psotka, Massey, & Mutter, 1988).

PLA OPERATIONS, FUNCTIONALITIES, AND CAPABILITIES

What happens as we begin to combine the above technologies, among others, into learning applications? What might we expect a PLA to be and do?

A PLA might be carried in a pocket or on a belt, worn as a shirt, or even implanted. It will operate wirelessly, accessing the global information infrastructure. It will include all the eagerly sought and widely used functionalities found on today's mobile telephones—e-mail, games, instant messaging, and even voice communication between people. It will use natural language, speech and/or text, to communicate—although other modes, including the language of science, mathematics, and engineering, will be available. It will provide a full range of media for interactions, including graphics, photographics, animation, video, and the like.

An important feature of PLAs will be their ability to allow participation in virtual environments and simulations, which could be used as virtual laboratories, mimicking equipment, situations, markets, and so forth. Virtual laboratories will allow the learner to test different hypotheses concerning the subject matter, try out different problem solving strategies and solutions, participate in collaborative learning and problem solving, and examine the effects and implications of different decisions. Because PLAs will be able to link to other PLAs, they will be able to contact experts and engage with other learners in virtual environments using software tools (for example, Soller & Lesgold, 2003) that identify and assemble potential communities of interest and enhance communication and collaboration within them.

PLAs will become intensely personal accessories. Through explicit and/or implicit means, they will develop, test, and modify models of the learner(s). These models will reflect each learner's knowledge, skills, abilities, interests, values, objectives, and style of encoding information. By using this information to access the global information infrastructure, PLAs will be able to collect and assemble precisely the learning objects that an individual needs to learn, solve a problem, or make a decision. In effect, PLAs may provide a polymath in every pocket, accessing the whole of human knowledge and information, filtering and adapting it for relevance and accuracy, and supplying it, on demand, in a form and level of difficulty that an individual learner is prepared to understand and apply.

By incorporating natural language understanding, PLAs may provide the goal-directed, on-demand, interactive conversations that have long been the goal of automated learning (for example, Uttal, 1962). The foundation of these interactions would be a mixed-initiative conversation between the learner and the PLA to achieve targeted objectives.

PLA INFRASTRUCTURE: PROGRESS

It seems reasonable to anticipate the ready availability of devices that can support PLA functions. Moore's Law, computer communications, wireless infrastructure, and the development of handheld computing should all help ensure this outcome.

The sharable learning objects required by PLAs are achievable, but not so easily assumed. These require effort and agreement among developers more than scientific breakthroughs. The global information infrastructure, currently instantiated as the World Wide Web, is obviously in place. It needs to be complemented by capabilities that automatically and precisely locate digital objects that will operate on most, perhaps all, of the PLA platforms to which they might be delivered.

Objects that meet these criteria have been specified by the Sharable Content Object Reference Model (SCORM) developed by the Advanced Distributed

Learning (ADL) initiative (Dodds & Fletcher, 2004; Fletcher, Tobias, & Wisher, 2007). SCORM ensures that learning objects developed in accord with its specifications allow them to be interoperable across computing platforms of many types, durable across different versions of underlying system support software, and reusable across multiple environments and applications. SCORM has received global acceptance as a specification and is progressing through the steps needed to be certified as an international standard. Whether or not SCORM is the ultimate specification for supporting PLAs remains to be seen, but it is an essential beginning. It has demonstrated the feasibility and acceptability of sharable learning objects.

The issue of access remains. Even if the global information infrastructure is well populated with interoperable, reusable, and durable objects, the problem of finding precisely correct objects to meet PLA user requirements remains. The Content Object Registry/Repository Discovery and Resolution Architecture (CORDRA) and the accompanying ADL Registry infrastructure have made substantial advances toward this goal (Dodds & Fletcher, 2004; Fletcher, Tobias, & Wisher, 2007). CORDRA uses metadata packaging and ontologies to allow substantially more precise location of digital objects than the text crawling techniques of many current search engines. Its precision can be expected to continue improving with the development of the Semantic Web and other emerging capabilities. As with SCORM, the eventual tool used by PLAs may or may not be CORDRA based, but its functionalities are likely to remain quite similar.

SCORM and CORDRA give us the means to populate the global information infrastructure with PLA-usable objects. We have only to create them. That appears to be happening. A survey of learning materials developed for industry and government found that over 4 million SCORM objects had been produced (Rehak, 2006). More have been appearing steadily since that survey was made.

The critical part of PLA functioning, then, remains the capability of servers to assemble learning material on demand, in real time, and in accord with learners' needs. PLAs will implement the generative, dialogue based, information-structured capabilities called for by intelligent tutoring systems. In effect, PLAs must participate in the design and development of the learning environment—virtual and otherwise—in addition to presenting it. They can become more than just delivery systems. This goal has not yet been reached, but it appears achievable. Still, there is much that can be done in the interim.

FINAL WORD

It seems likely that the technological trends and capabilities discussed here and carried forward by the ancient and continuing trend toward on-demand, anytime, anywhere learning will lead to the appearance of something very much like PLA based learning environments. We may reasonably expect substantially increased, globally available learning opportunities through enhanced access to education, training, problem solving, performance aiding, and decision aiding—or learning —made possible by PLAs. We can expect learning to become more responsive and effective through the continuous assessment, learner modeling, and interactions tailored on demand to learner needs that our technologies are making feasible. Finally, we can expect PLAs to vastly enhance access to and use of virtual environments for learning.

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